Faraday. The law of the motion of heat had not only been experimentally determined, but had been theoretically discussed by Fourier. The specific heats of the elementary bodies, as well as the heat developed in combination, had to some extent been determined by Dulong. And the law connecting the quantity of electricity produced in voltaic batteries with the number of chemical elements separated, had been discovered by Faraday. So far, however, these various branches of physics and chemistry had been subjects of separate and distinct study. No suggestion of equivalence had been made between the heat of combination of the elements and the electric current that would be produced by the same combination effected in the battery. That heat was developed in conductors by electric currents was known, but again there had been no suggestion of an equivalence between the heat and the resistance overcome. What are now known as the dynamo and motor had been invented by Sturgeon, showing that work could be done by the agency of electricity and electric separation effected by the agency of work, but again no equivalence between the amount of work and the energy of combination of the element in the battery had been surmised.

It was for Joule not only to suggest all these equivalences, but to experimentally determine all their numerical values[1] before he came to the equivalence of the work[2] spent in overcoming fluid, or solid, friction and the heat produced; and, again, between the work spent in compressing air and the heat produced.

The discovery of the mechanical equivalent of heat, important as it is, is but a poor expression for the outcome of this work, in which Joule converted what had till then seemed unquestionable cases of the destruction of energy into the most striking cases of its indestructibility. And although he propounded no theory, but simply declared himself to have believed in the indestructibility of *vis-viva*, or living force, he had, in the truest sense of the word, discovered the universal law that energy is indestructible and uncreatable. As Joule's work came to be apprehended, this law became accepted as its natural consequence in greater and greater significance, until now it stands the most general recognized law in the universe; relating not only to all matter but also the medium of space, which is thus found to possess the mechanical properties of matter and to be subject to the laws of motion.

The discovery of this law, bringing as it does the several branches of physical science into the domain of mechanical philosophy, fitly crowned all the work in physical science of the previous 150 years, of which it was the result. It also opened out a fresh platform for further discoveries—a platform which was immediately occupied in the erection of the compound sciences of thermodynamics, electrodynamics, and the dynamical theory of gases.

Joule was never prominently before the public. Ready to give himself with absolute devotion to the cause of science and the advancement of human knowledge, he yet preferred retirement and the calm labour of his laboratory to the excitement of public lectures and demonstrations. While he was keenly alive to the sympathy of friends, yet he worked for the most part alone, or in conjunction with one or other of the friends mentioned in the earlier part of this notice. He sought not at all for fame, but only for truth.

And yet honours in plenty came to him. He received honorary degrees from the most important Universities; he was honorary Fellow of many learned Societies at home and abroad. He was a Fellow of the Royal Society, and received from it the Gold Royal Medal in 1852, and the Copley Gold Medal in 1870. The Albert Medal of the Society of Arts was delivered to him from the hands of the Prince of Wales in 1880. In 1878 he received a letter from Lord Beaconsfield, announcing that the Queen had been pleased to grant him a pension of £200 per annum. This recognition by his country of his life of scientific labour was a subject of much gratification to Mr. Joule.

Special reference may be made to his connection with the Literary and Philosophical Society of Manchester. This commencing, as it practically did, at the age of fifteen, when he studied chemistry under Dalton in the rooms of the Society, continuing, by the most regular attendance at all the meetings, so long as his health permitted, and practically terminating with his death, must have been one of the most important circumstances of his life. Elected a member in the year of his greatest discoveries, 1842, he was Secretary in 1846, Vice-President in 1850, which office he held till his death, except during the ten years when he was President. He took the greatest interest in the welfare of the Society, and secured not only the veneration but love of all the members.

A man of science who left so deep a mark on his age ought to have been buried in Westminster Abbey, but unfortunately the necessary application could not be made, in consequence of the delay in the public announcement of his death. Prof. Osborne Reynolds, President of the Manchester Literary and Philosophical Society, has written to the *Times* urging that a monument should be erected in the Abbey, and that steps should immediately be taken to obtain, if possible, the consent of the Dean. This suggestion ought to meet with cordial and unanimous approval. Joule's name is one of which Englishmen may justly be proud, and the erection of a monument in Westminster Abbey would be the most fitting way in which they could express their appreciation of the splendour of his contributions to science.

THE LIFE OF SIR WILLIAM ROWAN HAMILTON.

Life of Sir William Rowan Hamilton. By Robert Percival Graves, M.A. Vol. III. "Dublin University Press Series." (Dublin: Hodges, Figgis, and Co. 1889.)

At last the third and final volume of Graves's life of Sir William Rowan Hamilton has seen the light. It was our pleasure in former numbers of NATURE (vols. xxviii. p. 1, and xxxii. p. 619) to have reviewed the two earlier volumes, and we have now to congratulate the University of Dublin on the completion of an adequate biography of the most illustrious student that has ever issued from its halls. This present volume, of which we are now to speak, is as portly as its predecessors. It contains not less than 673 pages, and a very important feature of the work is the correspondence between Hamilton and De Morgan, which occupies more than half of the entire bulk.

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[1] Man. Lit. and Phil. Soc., 1841–43; *Phil. Mag.*, ser. 3, vol. xix. p. 200.

[2] *Phil. Mag.*, ser. 3, vol. xxiii.

The two earlier volumes described the career of Hamilton up to the year 1854. The great mathematician was then forty-eight years old, and the first of his two stupendous books on quaternions had been just published for the admiration and astonishment of the scientific world.

The abundant recognitions of the epoch-marking nature of this work were naturally extremely gratifying to its author. From numerous scientific Societies at home and abroad honourable distinctions poured in upon him. But we can readily comprehend the biographer when he tells us that Hamilton specially prized the tributes from such friendly and competent judges as Sir John Herschel and a few others of similar calibre.

It must, however, be recorded that those who expressed, and no doubt felt such admiration for the book had not always, as they themselves admitted, any very complete acquaintance with the subject. Herschel, for instance, says:—

"I got through the first three chapters of it with a much clearer perception of meaning than when I attacked it some three or four years back, but I was again obliged to give it up in despair."

Even though Hamilton and his intimate friend De Morgan corresponded for twenty-five years—even though De Morgan was himself a capable mathematician, whose labours led him in some degree towards the same line of investigation from which quaternions originated—yet he never succeeded in obtaining a competent acquaintance with Hamilton's theory. Most scientific men were apt to feel contented if they knew enough to make them reverence the awful volume which every mathematician likes to see on his shelves, but which we generally find that he likes to leave there.

It must be admitted that the hopes which Hamilton entertained as to the utility of quaternions as a mathematical calculus have not yet been fully realized. It seems to be the essence of modern mathematics that it should partake of the nature of exploration. For the furtherance of many departments of mathematics which are now ardently cultivated, a general and all-embracing calculus is not found so useful as are especial methods particularly contrived to the subject in hand. We may cite as an example of what we mean Klein's lectures on the Ikosahedron, which were so admirably reviewed in a recent number of NATURE (May 9, p. 35). The theory here involved may be regarded as typical of all that is best in modern mathematics; yet the methods which have been adopted are not those of any comprehensive calculus like quaternions; they are processes and lines of reasoning which naturally arise from the special character of the subject, and the same may be said with regard to other branches of mathematical research. Of course everyone admits the magnificence of quaternions viewed as a mathematical theory. It is indeed "a tract of beautiful country"; but, for the reason, apparently, that we have mentioned, it would seem that up to the present, at all events, the hopes which Hamilton entertained that quaternions should be largely used by mathematicians as a calculus have not been realized.

As to the value of quaternions we quote the following words of Prof. Tait, which occur in the preface of his well-known treatise on the subject, for probably there is no other living mathematician who could speak with equal authority:—

"The numerous examples I have given, though not specially chosen so as to display the full merits of quaternions, will yet sufficiently show their admirable simplicity and naturalness to induce the reader to attack the lectures and the elements; where he will find, in profusion, stores of valuable results, and of elegant yet powerful analytical investigations, such as are contained in the writings of but a very few of the greatest mathematicians."

The extraordinarily laborious habits of Hamilton are constantly referred to in this volume. He frequently speaks of working for twelve consecutive hours at mathematical research, and when immersed in these trances of discovery his regular meal hours were forgotten, and, unfortunately, he used to resort unduly to alcoholic stimulant. His relaxations, such as they were, may be conjectured from the following paragraph (p. 186) from a letter addressed to Dr. (now Sir Andrew) Hart by Hamilton the year before he died:—

"The fact is, that one of my early tastes was for metaphysics, and something has lately occurred to revive it. Another was for Eastern languages, and I chanced yesterday to light on the first sheet of a 'Persian grammar' written by myself forty years ago. These things, with others, may occasionally relax the bow—'*Non semper tendit*' but 'many tastes one power,' and my only *power* is mathematics."

As we have already stated, both the study of poetry and the writing of poetry were favourite recreations with Hamilton; and as this subject is so frequently mentioned in these volumes it may be well to mention what the biographer—himself an excellent judge—records on the matter (p. 128):—

"I will not here refrain from stating my own opinion, strengthened by that of friends specially competent to judge, that Hamilton's poems have, both in their diction and in their matter, qualities of enduring value; that, speaking generally, they are and will always be felt to be fresh, graceful, fervid expressions of states of feeling and thought, interesting in themselves and possessing a heightened interest from their being the heart's utterances of a man of gigantic mathematical powers and of strong and deep affections; and a few of them, it may be added, are so happy in thought and expression as to claim their place in the poetry of his country."

The closing years of Hamilton's life were spent in the preparation and the passing through the press of his second great volume, "The Elements of Quaternions." In the summer of 1865, his stupendous labours had at last reached their termination. His health, which had for long been failing, now gave way, and at last, from a complication of ailments, which included gout and bronchitis, he died on the 2nd of September, 1865.

An interesting chapter on the "characterizations" of Hamilton and his work closes the biographical part of the volume. A letter from Prof. De Morgan to Lady Hamilton (p. 215) contains the following passage:—

"I have called him one of my dearest friends: for I know not how much longer than twenty-five years we have been in intimate correspondence of most friendly

> agreement or disagreement, of most cordial interest in each other, and yet we did not know each other's faces. I met him about 1830 at Babbage's breakfast-table, and there for the only time in our lives we conversed. I saw him a long way off at the dinner given to Herschel about 1838, on his return from the Cape, and there we were not near enough, nor on that crowded day could we get near enough to exchange a word; and this is all I ever saw, and, so it has pleased God, all I shall see in this world, of a man whose friendly communications were among my greatest social enjoyments and greatest intellectual treats."

Hamilton was scrupulously sensitive about the feelings of others, and in his scientific work he took the most elaborate precautions that every particle of credit should be duly assigned to every mathematician whose labours had in the minutest extent anticipated his own. He had high personal courage and a keen sense of honour. It is recorded that he sent a hostile message to one who had challenged his veracity, and a due apology was exacted. The only approach that Hamilton ever had to a controversy about priority arose in the case of the discovery of conical refraction. MacCullagh put forward a claim to have virtually anticipated Hamilton. The sound judgment and lofty sense of right which were so characteristic of Humphrey Lloyd here averted what would have been an unpleasant dispute, and MacCullagh withdrew his pretension.

De Morgan says that in Hamilton's youth he used to be styled among his playmates the "defender of the absent," and from the same source we learn:—

> "He relished the extremes both of simplicity and splendour; though in his own habits and manners as plain as possible, he thought much of the comforts of others and lightly of his own. When some housebreakers were caught on the premises and detained until they could be carried before a magistrate, he amused his family by directing that the fellows should be asked whether they preferred tea or milk for breakfast. A full memoir of his private and public life would present a genial combination of intellectual greatness, moral goodness, and piquant peculiarity of thought and manner, all brightened by never-ceasing benevolence of feeling, and toned by rare gentleness of manner."

Hamilton has left behind him an enormous bulk of manuscripts, of which not less than sixty great volumes have been deposited in the College Library. There are also many other papers unpublished, as, for instance, a stupendous letter to Dr. Hart, which contained about 240 large folio pages and a postscript of 60 additional.

The distinctive feature of this third volume of his life is the De Morgan correspondence, which, like the correspondence between Bessel and Olbers, will retain a permanent value. The opening letter of the series is from De Morgan, on May 8, 1841, in which he says: "I hardly know whether you remember that we made a little personal acquaintance some twelve years ago, when you were in London." The last is also from De Morgan, and the date February 3, 1865, relative to an application for a pension for the widow of the late Prof. Boole.

The correspondence, though largely on matters mathematical, ranges over a multitude of topics, classical and literary, logical and metaphysical, humorous and domestic. It sometimes glances at theology, occasionally condescends to refer to a practical question like the decimal system, but is almost wholly free from any reference to what are now generally known as the experimental or natural sciences, though we do indeed read of an electro-magnetic quaternion. From such an astounding mass of 400 pages it is difficult to cull passages which shall be regarded as samples. The collection is too heterogeneous to admit of such a process. It is, however, impossible not to feel how admirably the biographer has accomplished this part of his task. He has extracted from a mighty bulk of correspondence a collection so interesting that, after reading them through, we do not see any which we could wish to have been omitted.

It was three years after the interchange of letters had begun, and when Hamilton was thirty-nine years old, that De Morgan writes (p. 258):—

> "I hope you are well, and taking care of yourself. Nobody gives you a good character in the second particular.
>
> "The Astronomer-Royal in this country always lays down his work the moment he feels wrong, and plays till he feels right again. You have too much of our stock of science invested in your head to be allowed to commit waste. You are only tenant for life, and posterity has the reversion; and I don't see why you should not be compelled to keep yourself in repair."

Traditions of the state of Hamilton's study are still current. The awful masses of books and papers accumulated on the floor to such an extent that a lane had to be preserved for the perambulations of the Professor, who did much of his work standing at a blackboard, or walking up and down. Thus we can understand him writing to De Morgan on October 3, 1849 (p. 279):—

> "If I lay a letter out of my hands for a few hours, without answering it, I am sure to find that it has been swept away and covered up, for the time, by the Charybdis of my other papers. No doubt, every such missing treasure may be expected, at some future time, to emerge to view, and may then be suddenly seized, by a bold and ready hand. Thus, from month to month, or at least from year to year, I find a note or two of yours eddying upward to the light; but, for the instant, your last long (and welcome) letter is invisible. However, I remember much of its contents, and shall send something now in answer to one, at least, of its 'loose thoughts.'"

As already mentioned, De Morgan could never be induced to devote himself sufficiently to quaternions to understand them. He often alludes to this, thus writing on October 11, 1849 (p. 283):—

> "Nothing about quaternions will bore me, if I can only make it bore through me. Ink must be cheap in Ireland if you can afford to waste it on such a supposition as that."

Many amusing references are made by De Morgan to the contrast between his friendship to the Sir William Hamilton of Dublin, and his notorious controversies with the Sir William Hamilton of Edinburgh. Thus, on April 14, 1850 (p. 286):—

> "Be it known unto you that I have discovered that you and the other Sir William Hamilton are reciprocal polars with respect to me (intellectually and morally, for the Scotch baronet is a Polar bear, and you, I was going to say, are a Polar gentleman, only I thought perhaps you might go and say I called you an Esquimaux). The intellectual polarity is of the kind, $\phi\psi(x) = -x$. When I send a bit of investigation to Edinburgh, the William

> Hamilton of that ilk says I took it from him. When I send you one, you take it from me, generalize it at a glance, bestow it thus generalized upon society at large, and make me the second discoverer of a known theorem. He cuts my legs off; you make a pair of legs grow out of my head, and turn me upside down to stand upon them. His process after yours gives $\phi\psi(x) = -x$. Reciprocal polarity the last and most agreeable; your process involves no writing of pamphlets."

The gradual production of the books on quaternions are indicated by frequent allusions in the letters. On November 26, 1851, Hamilton writes (p. 291):—

> "My book on the quaternions is advancing rapidly. I have just been correcting the slip which will bring it somewhat beyond 440 octavo pages. I first aimed at 200, but shall now congratulate myself if I get off under 500 pages. [It was ultimately 888.] You should be most welcome to copies of all the sheets hitherto printed, if I fancied that you would accept them, in the present state of the publication. In fact, I should *like* to send them, but think it not quite fair to *force* what may be thought a confidence on anyone."

To which De Morgan replies, in words that other authors will heartily appreciate (p. 293):—

> "I beg you will send me the part printed, without scruple. There is a pleasure in reading while anything that strikes one may do service; it is the reviewer's feeling Christianized."

So much has been said about Hamilton's poems, and of the opinion he entertained of them, that it is well to read an authentic version of his own view of the matter in his letter of January 21, 1852 (p. 320):—

> "If among your many and deep researches you have made psychology, as a sort of branch of natural history, one of them, you may feel some little interest in the following problem, which has often puzzled myself.
>
> "Among the persons who know anything about my existence and my writings, I suppose that the majority would admit me to be a mathematician; while all, or nearly all, would say that I could only be regarded as a poet by courtesy.
>
> "Does it not seem, then, to contradict one of the very tritest sayings about human nature that I care little, or not at all, about criticisms on my poetry, such as it is, while I own myself to be actually sensitive on the score of my mathematics?
>
> "Wordsworth did me the honour to cut up, in a more slashing style than yours, some of my early poems. I think that I was less flattered than indifferent, although I did most highly prize the advantage of an intimacy with him.
>
> "Slash away at my sonnets; but spare me, if you honestly can, a little praise for the quaternions, or, what will be far better, allow me the honour of *assisting* you to *use* them as a calculus, for such they certainly are."

Hamilton complains that he is ridiculed about the quaternions by people who know nothing of the method. De Morgan advises him to preface the book with a systematized body of results, on the ground that "every book should be provided with some palisade against mere talkers. . . . You will find the table of contents a useful outwork."

It would seem there was another class of quasi-scientific men of whom Hamilton, not without reason, had some dread, for we read (p. 360):—

> "A story goes, that a person who read more than he digested once told a friend of his that he had heard people talk of 'Euclid,' and that he was curious to read the work. The other lent him a copy, and was surprised to find the borrower return it the next day with many thanks. 'What, have you read it?' said the lender. 'Yes, thank you,' replied the borrower. 'Read it?—read Euclid *through* in that short time?' 'Oh, if you mean the A's and the B's and the C's, I skipped all those.' The 'Quaternions' as well as the 'Formal Logic' may meet with some readers of that stamp."

To which De Morgan replies (p. 362):—

> "When you tell the story about Euclid, remember that the man left out the A's and the B's and the C's and the pictures of scratches and scrawls. I once met a man, no strong mathematician, who said he read Airy's 'Gravitation' through on a bench in the front of his house."

We have learned in the earlier volumes of the almost miraculous talents which Hamilton displayed as a child for the acquisition of languages. It is therefore interesting to find him saying on April 16, 1852:—

> "As to Sanscrit and Persian, I do not pretend to read them *now;* but my childish acquaintance with various languages may, as I have often since thought, have assisted me in my maturer study of mathematical symbols, and even in my attempts to enlarge the limits of mathematical expression."

An interesting letter to De Morgan on March 14, 1854, gives Hamilton's views on Auguste Comte's "Cours de Philosophie Positive," from which the following extract may be cited (p. 475):—

> "These specimens, which I could easily multiply, may suffice to justify a profound distrust of Auguste Comte, wherever he may venture to speak as a mathematician. But his vast general ability, and that personal intimacy with the great Fourier which I most willingly take his own word for having enjoyed, must always give an interest to his *views* on any subject of pure or applied mathematics."

There were often long intermissions in the correspondence, generally on Hamilton's side, until at last De Morgan, by some genial and humorous attack, would succeed in reopening it. Witness the following:—

> "If you are dead and buried, why can't you say so like a man, instead of leaving me to infer it from your silence."

And again on April 29, 1855 (p. 495):—

> "Rouse out from the quaternions and write me a line. Remember that I, who have studied biography, and especially looked at the psychology of inventive mathematicians, do positively make affidavit, that if a man do not fallow, and shift courses, as they say, or used to say, in farming, he will put his head *out of heart*. If I had the power—supposing it true, as I hear, that you will not let quaternions alone for a while—I would put you into the commissariat, and make you copy out Balaklava stores, for six months. How are you all?"

These last lines remind us of a prescription recommended for another eminent mathematician, whose thoughts were apt to soar too far above terrestrial things. It was that he should serve for a couple of years as conductor to a London omnibus.

An appendix contains in the words of Hamilton himself what is designed to be as popular an account of the doctrine of quaternions as the subject will admit. It consists of two portions: firstly, an unfinished letter to his uncle, the Rev. James Hamilton, dated September 11

1846; the other an "elementary sketch," written after the publication of his volume of "Lectures on Quaternions." He here again insists on the combination of the notions of time and space in the quaternion.

> "And how the One of Time, of Space the Three
> Might in the Chain of Symbol girdled be."

The appendix also contains Hamilton's account of Mädler's attempt to show that the Pleiades are the central group of our sidereal system. The doctrine was unworthy of Hamilton's attention, and these pages are the only ones in this volume which we would gladly have seen omitted. Of infinitely more value are the remaining pages, in which we find a carefully compiled catalogue of all Hamilton's writings. There is also an interesting list of the chief unpublished manuscripts of Hamilton which have been preserved; and finally, before the capital index is reached, we have an enumeration, to which Prof. Tait has contributed, of the chief works of other mathematicians in which the quaternions have been employed.

It is impossible to read these volumes without acquiring a feeling of admiration amounting almost to reverence for the majestic intellect that they so adequately portray. In his youth Hamilton set before himself with deliberate aim the attainment of excellence in scientific work. Throughout his life he spared no pains, he flinched from no labour, to attain his ideal. With wonderful singleness and concentration he devoted his life to work. His career affords another illustration of the very close alliance if not actual identity between genius and the capacity for taking pains. If the quality of his work could not be surpassed, most assuredly its quantity could hardly be rivalled, and yet when we take leave of this work and ponder on the lessons it teaches it is perhaps hardly on the intellectual side of Hamilton's life that we shall find ourselves meditating. It is impossible to follow that exquisite correspondence between Hamilton and De Morgan without thinking of the rare but well-deserved good fortune which gave to De Morgan such a correspondent as Hamilton, which gave to Hamilton such a correspondent as De Morgan. On both sides these letters breathe a lofty spirit of truthfulness and honour and of attachment to whatsoever things are just and noble. Each shows a charming conception of the respect due to his friend and of the respect due to himself. Friendship such as these two men enjoyed was indeed a choice privilege. Hamilton shows himself not only as the consummate mathematician and philosopher, not only as the scholar and the poet, but as the high-minded gentleman with whom exalted conceptions of duty were habitual.

Finally, we must express our obligations to Mr. Graves for the admirable way in which he has completed his monumental task. He was intrusted with the preparation of the biography by Hamilton himself, and for laborious years he has devoted himself to the charge which his deceased friend laid upon him. Materials he had in abundance the most prodigal. He has selected copiously and he has selected judiciously, and he has told his wonderful story with a literary gracefulness that we most gratefully acknowledge. The memorable volumes of the "Lectures on Quaternions" and the "Elements of Quaternions" have a place on the shelves of all scientific libraries which are worthy of the name. Beside them should be ranged the three portly volumes in which Graves has recounted the life of that astonishing genius by whom Quaternions were invented.

THE ENGLISH TRANSLATION OF WEISMANN'S "ESSAYS."

Essays on Heredity and Kindred Biological Problems. By Dr. August Weismann. Authorized Translation, Edited by E. B. Poulton, Selmar Schönland, and Arthur E. Shipley. (Oxford: Clarendon Press, 1889.)

THIS is the fourth volume of a very useful series of translations of foreign biological memoirs, and the Delegates of the Clarendon Press are again to be congratulated on their choice of subject and editors.

As the editors' preface tells us, since Mr. Shipley's article, entitled "Death," in the *Nineteenth Century* for May 1885, first called the attention of English biologists to Prof. Weismann's essays, the interest in that author's conclusions and arguments has become very general. This interest has been stimulated and widened by the articles of various authors in NATURE, by Prof. Lankester's addresses at the Royal Institution, and, above all, by the great discussion introduced by Prof. Lankester at the meeting of the British Association in Manchester. No doubt a translation is superfluous, in these days of international science, to most biologists. But this is much more than a technical treatise on a technical subject. It is of interest to that far wider circle of readers and thinkers devoid of the time or the opportunity to wrestle with the involved German of the original. For to most the pith and kernel of the whole book is the criticism, perhaps the refutation, of the theory of the inheritance of acquired characters. That theory is of immediate importance to biology, but it is of equal, if remoter, importance to education and morality. We are certain that biologists do not enjoy a monopoly of education: we are by no means certain that they enjoy a monopoly of morality.

The translation is very accurate and unusually elegant: the foreign idiom has, to a large extent, been avoided, and there is little trace of the intricacies of Teutonic inversion. The footnotes are exceedingly useful, and many of them introduce important collateral matter. For instance, on p. 172, a concise and clear account is given of Mr. Francis Galton's earlier and somewhat parallel explanation of heredity.

The typography is excellent, but the absence of spaced type—a device of great utility in the original—is to be regretted.

The essays are translated in chronological order from the revised German editions. And so, by a consecutive perusal of the book, an historical conception of the wonderful series of inductions and inferences may be gained. Among the many converging lines of thought and work that led to the conception of the germ-plasma as the basis of heredity, two seem most clearly marked. In a prolonged study of the Hydromedusæ, Dr. Weismann discovered that the generative cells were formed only in certain localized areas. These special areas vary in position in different species, and the differences in position correspond to the different stages in a process of